

SYSTEMATIC CREATIVITY ALGORITHMS: NEW PARADIGM OPPORTUNITIES FOR ARTIFICIAL INTELLIGENCE

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Abstract

This paper examines one of the main limitations in present-day computer systems – the lack of ability to make *useful* creative leaps – and suggests how some of the tools of TRIZ might be adapted to produce at least the first few tentative steps towards a viable and practicable computer-aided innovation capability. The paper is divided into three main sections; a first examining the importance of the discontinuous ‘jump’ in the creative process; a second exploring a so-called Para-Discontinuity Effect – in which the 40 Principles of classical TRIZ are re-formulated in a manner that makes them amenable to deployment in an automated algorithm; and then a third in which we attempt to chart the relatively unmapped territory between knowledge and wisdom and explore the role that computer-aided innovation systems might play in bridging what may currently be seen as a rather large gap

Keywords: systematic, innovation, discontinuity, TRIZ

1. Introduction

Systematic innovation research shows how systems, paradigms and modes of thought all hit reasonably ‘clever’ things have been achieved by man-made systems, there fundamental limits beyond which they will not go (Figure 1). Despite great leaps forward in the discipline of artificial intelligence in recent times, it appears clear that although some is very little that has been achieved that can be considered to be truly ‘intelligent’.

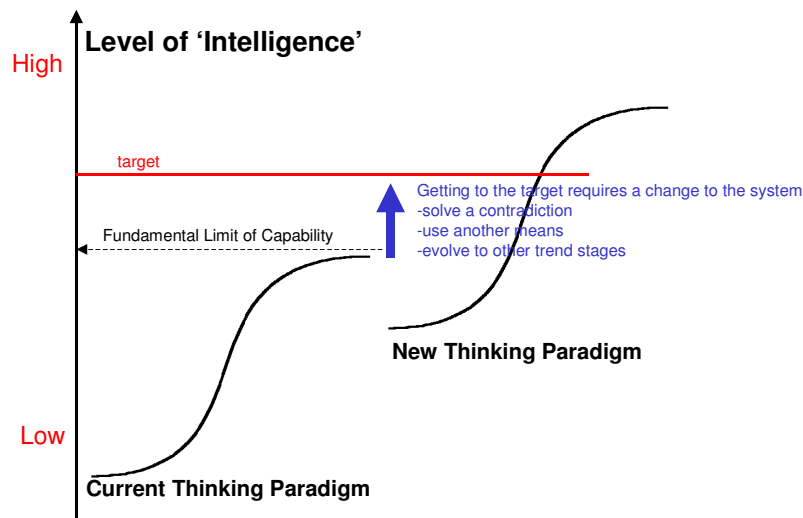


Figure 1: Systems Hit Fundamental Limits

Artificial intelligence systems, whether constructed in a top-down or bottom-up manner, have primarily resulted from traditional academic thinking paradigms. Such thinking modes involve patterns constructed from the predominantly analytical, judgemental, either/or thought processes originally instigated by Aristotle. There is considerable evidence to suggest that while such strategies are in many senses useful, they possess qualities that mean several fundamental limits have been reached. Put simply, artificial intelligence as we currently know it has hit its own fundamental limit. To travel beyond this limit requires new paradigms.

The paper introduces such a paradigm. New thinking models based on the strategies of the world's most successful creators are emerging through the Theory of Inventive Problem Solving, TRIZ. These models build on the fact that 'creativity' is a rather more predictable, programmable construct than most people perhaps imagine is possible.

The basic start-point of TRIZ is the codification of excellence from all forms of human endeavour. A large part of that codification has been based on the analysis of patents. What these studies show that is relevant to the modelling and machine reproduction of creativity is:-

- 1) the key creativity instigator is contradiction – a difference or mismatch between the current state and a desired state.
- 2) the key mechanics of the creative act then involve the resolution or elimination (as opposed to traditional trade-off or compromise approaches) of these mismatches.
- 3) The existence of only a small number of possible strategies through which such contradiction elimination can take place. In fact, the research shows, there are a very small number of possible strategies.

2. The Para-Discontinuity Effect

The majority of systems react only when stimulated by some kind of external signal. This signal might be something good or something harmful. Whichever it is, however, the main point from the perspective of provoking the system into 'doing something' is that a difference between the current state and a new 'desired state' has emerged. In other words, a contradiction has occurred. Natural systems learn to respond to such contradictions by trial and error; this happens in such a way that if an attempted response to the contradiction is 'incorrect', the system eventually remembers not to use that strategy, whereas if the response is successful, then that response is recorded as 'successful'. Learning, in humans at least, takes place by the cumulative testing and reinforcement of these 'successful' responses. The more a particular response results in a positive outcome, the more likely it is that the brain will remember that response. These learned responses are often called 'common sense'. This type of learning is fundamental in allowing us to function in modern society – 'common sense' is the thing that gets us safely across a busy road, without us having to 'think' about what we are doing. Another description for this mode of thinking, however, is 'psychological inertia'. Psychological inertia describes the phenomenon in which the 'automatic' learned response actually turns out to point us in the wrong direction. As a crude generalisation, we might suggest that the 'automatic' response is the one we require 99% of the time. But there is then the 1% situation – the one when the 'common sense' solution turns out to be wrong, and what is actually required is a 'creative' solution. By way of a trivial example, it might be possible to imagine a threat conflict in which we require a fight-versus-flea decision. This might mean imagining a person being chased by someone or something. The person has learned their own set of answers to the 'fight versus flea' conflict. Let's say that in a given situation, they are presented with a series of corridors, and that his system has suggested that 'flea' is the most appropriate response. Having made this decision, the person then runs along the corridor trying to escape from the perceived aggressor. The 'common sense' response then tells him,

having made this ‘flea’ decision, to keep running in order to maximise the distance between themselves and that aggressor. In terms of the artificial intelligence version of this situation, there have been two choices – fight or flea, and having chosen the second, the ‘flea’ algorithm works to maximise a ‘distance’ parameter. Most people faced with this same situation would do exactly the same thing – it is ‘common sense’ after all. But the Para-Discontinuity Effect is different. This Effect enables a person to be able to jump out of this ‘common sense’ mode to derive novel solutions to the situation. A highly non-scientific, but nevertheless excellent example of this Para-Discontinuity Effect in action is James Bond. In several Bond films featuring exactly this fleeing-along-corridor scenario, we see him adopt a strategy in which his brain jumps out of the mode of thinking ‘run along corridor’ into the mode that says ‘hide on the ceiling of the corridor’. And then the next thing we see is the aggressor (still in ‘run along corridor’ common sense mode) running past Bond, leaving Bond to drop back onto the floor and travel the other way in safety. We might call this breaking out from the ‘common sense’ approach ‘creativity’ or the Para-Discontinuity Effect. ‘Hide on ceiling’ being a creative response that is both paradoxical and discontinuous.

The findings of TRIZ researchers have shown that the resolution of contradictions like the ‘fight-versus-flea’ one described above – but actually found in every kind of engineering and natural system – can only be performed by a very small number of strategies. The ‘hide on ceiling’ response being one titled ‘Another Dimension’. This is the strategy that says ‘if you are travelling along a 2D surface; make use of the third dimension’.

The total number of these contradiction breaking strategies is illustrated in Figure 2 below. More details of these strategies can be found in Reference 1.

	Blessing In Disguise	Self-Service	Function	
	Space	Time	Interface	
Segment	1	18, 19	2	Number
Magnify			38	Size
Re-shape	3, 4, 14, 17	15	12, 16	External Shape
Modify	30, 31, 32, 36, 40	9, 10, 11	8, 37	Internal Structure
Substitute	26, 28, 29, 35a	27, 34	23, 24	Content

Figure 2: Contradiction Eliminating ‘Creative Response’ Matrix

(Numbers in boxes relate to original TRIZ Inventive Principle numbers – their sequence has been altered into this more logical structures since the original TRIZ structure and sequence possesses many shortfalls in terms of logic flow and overlap)

What the figure implies is that there are only so many possible responses to a conflict situation. They can be categorised into four main areas:-

- at the top of the chart, are three higher level creative responses based on the pillars of TRIZ – maximum use of existing resources (in which even the harmful things can become useful things – hence ‘Blessing In Disguise’), increasing ‘ideality’ – in which systems learn to solve problems ‘by themselves’, and functionality (with the discontinuity opportunity provided by a change of function).
- At the next level there is a 5x3 Matrix concerned with ‘space’, ‘time’ and ‘interface’ issues. For each of these, the Matrix suggests, there are only five possible contradiction eliminating responses – change the number, change the size, change the external shape (here we include things like asymmetry, local feature changes, curvature, and increasing use of dimensionality – this is where the aforementioned ‘Another Dimension’ features), change the internal structure (addition of holes, composite structures, colour changes, etc)

These strategies represent a bottom-up ‘creative response’ algorithm model. This model is currently being programmed into a virtual software-agent system, in which the agent can be made to learn and implement creative responses to any conflict situation into which it may be placed.

2.1 A Simple Example

It is possible to demonstrate the sorts of creative response that the prototype software agent is capable of making through a simple design example. For this, we will use a classic TRIZ case study, the toothbrush. Despite their long development history and apparent technology maturity, here we may see an engineered system still possessing a number of problems and conflicts. One of the important unresolved design conflicts relates to the desire to have stiff, resilient bristles capable of removing debris from the surface of teeth, while at the same time we do not want the possibility for those bristles to damage the more vulnerable gums. The typical design response to this kind of conflict situation is to try and identify the ‘optimum’ level of bristle stiffness that will do the best possible tooth cleaning job, without causing gum damage. More accurately – to do justice to the world’s toothbrush designers – a manufacturer will typically offer a range of different toothbrush models, each with a different level of bristle stiffness.

One of the key ideas in the TRIZ method is that whenever designers find themselves looking for this kind of ‘optimum’ solution, they have missed a significant innovation opportunity. The ‘optimum’ solution in TRIZ terms is the enemy of the ‘ideal’ solution. By itself this distinction between ‘optimum’ and ‘ideal’ may just come to define the difference between improvement and innovation. Genuine innovation, in TRIZ terms at least, has nothing in common with optimization, other than that the ‘optimum’ solution represents the start of the definition of a design conflict that the TRIZ tools will then help to eliminate.

The Para-Discontinuity Effect is the thing that creates the discontinuous jumps that will occur in a design in order to ‘eliminate’ identified conflicts. The ‘creative response’ triggers identified in Figure 2 represent the only known means by which the toothbrush might evolve and create a conflict-resolving innovation. Table 1 below illustrates some of the para-discontinuity directions that the software agent is able to make automatically:

Table 1: Automatically Generated Toothbrush Para-Discontinuous Evolution Triggers

	Space	Time	Interface
Handle	Hollow, multi-hollow foam plastic	Thermochromic Rheopexic	L/R handed Ergonomic

	Holes Surface protrusions/grooves Lotus-Effect Flexible, curved, 3D profile Asymmetry Multiple materials, fibres Eliminate handle	Pulsed Multi-function Timer Piezo-electric Electrical, rotating	Transparent Feedback Shape-change Shape-memory Merge toothpaste Merge floss
Head	Hole, holes, capillary pores, hollow Tapered, waisted, etc Projections Flexible, fluid Surface grooves, protrusions, dimples Bigger, smaller Detachable, twin-head Eliminate head	Pulsed vibration Multi-function Rotating, vibration Co-ordination with Handle/bristles	Multi-colour Transparent, mirror Feedback Variable stiffness Additional function Measurement, sensor Opposite function Something in hollow
Bristle	Increased number Hollow, partially hollow Non-circular section (oval, triangle, rectangle, crescent, etc) Ribbed, spirals, flutes Tapered, curved, various heights, different angles Different stiffnesses Asymmetric, non-uniform spacing Longer, shorter Elongated, finned Bristle-on-bristle Bristle-in-bristle Nano-profile Fluid or field based New material, composite (stiff in some places; flexible in others)	Co-ordination between bristles, Inter-locking, Travelling wave Vibration, Ultrasonic, resonance Different stiffness in back and forward motion Twist/untwist	Different colours Multi-colour Colour change Shape change Thermopexic Measurement, sensor Additional functions Something in hollow

Bearing in mind that the ‘creative response’ triggers are the result of the analysis of close to three million successful solutions, it is our prediction that sooner or later we will see many of these ideas emerge onto the market. Some, like colour changes and alternative bristle arrangements, appear already to be emerging, while others – ribbed bristles – appear to offer considerable opportunities to create a more effective design. Given their role as ‘signposts to good solutions’, one way of thinking about the triggers is that they help designers to listen to the ‘voice of the product’. Based on the successful design evolution in other fields, for example, a toothbrush bristle with a smooth surface is ‘trying to tell us’ that it wants to have grooved, ribbed or fluted surfaces, and that such surfaces will do something useful for the user.

3. From Knowledge To Wisdom

While undoubtedly representing a significant forward step, the ability to automate the process of generating creative solutions is comparatively small in comparison with the next missing step along the road to a genuine computer-aided innovation process. The bigger step is the one between the creation of generic creative solutions and the realisation of a practical, relevant actual solution. Figure 3 illustrates a generalised form of the TRIZ process. What we see in this figure – although infrequently recognised as such – is the difference between ‘knowledge’ and ‘wisdom’. A good way to elucidate this difference involves consideration of context. Many organisations talk about the importance of knowledge, ‘knowledge management’ and ‘knowledge creation’. Each is clearly an important aspect of the innovation process. Knowing that there are 200+ ways to move a liquid, for example is important ‘knowledge’ and increasingly we may observe companies classifying knowledge in such functional terms (see Reference 2 for example). Knowing which one of those ways best suits your specific context, however, is about wisdom. Likewise, obtaining several dozen para-discontinuous design evolution suggestions is useful knowledge, but knowing which of them will have any relevance to the clean-teeth-but-don’t-damage-gums conflict is wisdom that only someone with some domain knowledge will be able to connect.

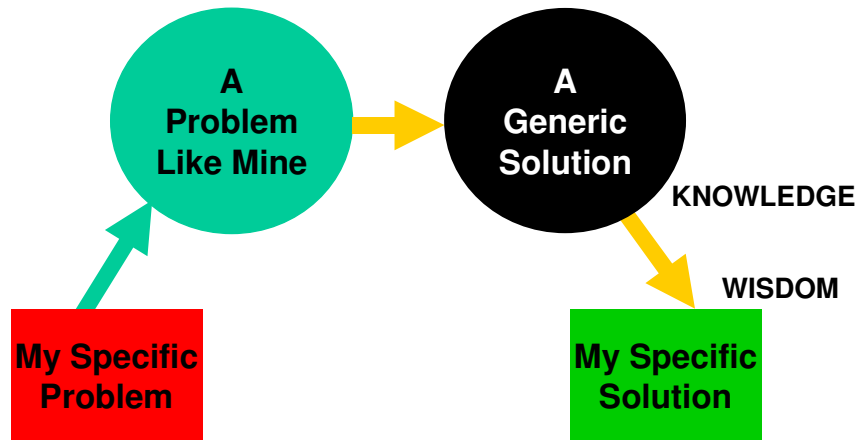


Figure 3: TRIZ Process And Connection To Knowledge And Wisdom

The missing link between knowledge and wisdom is context. Wisdom equals knowledge plus context. The full Para-Discontinuity Effect is very definitely about the sum of knowledge and context; it is one thing to have knowledge about an inventive leap called ‘Another Dimension’ programmed into a person’s brain, but a whole different thing to know when, where and how to apply that inventive step.

The human brain is a tremendously powerful parallel processor. As may be observed in many of the case studies presented in Reference 3, human instinct – when it is working effectively (when we achieve a condition of ‘flow’ for example) – is an extremely effective context-engine; able to (mostly sub-consciously) take in enormous amounts of information and knowledge, and make a best fit to the surrounding context. The brain is an extremely effective instrument when it comes to managing such large quantities of knowledge and contextual information. As James Bond is running along those corridors, he is parallel processing massive amounts of data from each of the senses, and somehow, from that mass of incoming information comes a near-instantaneous connection between the glimpse of an overhead air-conditioning duct outlet and the deployment of the ‘Another Dimension’ creative leap. This is

almost the polar opposite of ‘keep it simple, stupid’. It is about observing and making sense of the whole thing.

Now this ‘it’s the whole thing, stupid’ phenomenon causes a real problem in our desire to create a context engine. As independent (and probably most advanced) AI thinker Steve Grand has reported (Reference 4, 5), an algorithmic approach to the context/knowledge problem is ultimately doomed to failure. Lucy, Grand’s test platform, like human infants, has ‘learned’ all it knows about the world from first principles. Lucy’s context engine, again like human infants, has (and continues to) evolve through a process of trial and error.

Put Lucy in the James Bond corridor situation and unless her context engine has ‘learned’ that a steel grille equals air-conditioning duct equals man-sized cavity behind it equals hiding place, then even if she is programmed with ‘Another Dimension’ and for that matter all of the other creative leaps, she will not realise 007’s answer. The para-discontinuity will, in other words, not happen.

3. So Where Next?

Having the ‘creative responses’ programmed, is of course, still a major step forward. As yet, neither Lucy nor any other piece of artificial intelligence has acquired the knowledge they contain. Combine the creative responses with Lucy’s capability to ‘learn’ contextual knowledge, however, and we may well have the start of a genuine leap towards computer-aided wisdom. Everything Lucy does is learned bottom-up through trial and error. Maybe, the links between knowledge and wisdom cannot be programmed, but maybe too, just like humans, Lucy and her kind can learn which creative leaps work in which contexts and which do not. One thing is for sure; they will be able to learn more quickly and more systematically than even the most innovative human brain.

Neither Lucy nor any other artificial intelligence will pass the Turing test or any other equivalent until it is able to make the same sort of creative leaps and context-connections humans are routinely capable of making. The 18 strategies contained in Figure 2 define the current scope of possibilities available to the human mind. Implementation of these strategies into the virtual robot is beginning to demonstrate that a viable ‘creativity algorithm’ is not far from practical reality. The link between this capability and learned context; between this and Lucy, is an important next step along the road.

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